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THE LEC DEVICE – EXPLORING THE PARAMETER SPACE

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ABSTRACT.

The LEC or 'Lattice Energy Converter', invented and patented by Frank Gordon and Harper Whitehouse is, in its simplest form, a 2 electrode dry cell with modest electrical output, novel in that the only conductive medium between electrodes is an ionised gas or vapour.

Replication and study of the LEC as described by Gordon and Whitehouse have been carried out by Jean Paul Biberian, Antonio Di Stefano, Jacques Ruer, Alan Goldwater, this author and others, all encouraged by its simplicity and replicability.

LEC research published suggests that it requires the wet co-deposition of Pd or Fe with a hydrogen isotope onto the surface of a working electrode (WE). When dried and placed in close proximity to but not in contact with a counter-electrode (CE) a very persistent voltage, typically of 200-800mV, is immediately measureable. The WE and CE may be short circuited many times without reducing voltage output, and output voltage recovery time is rapid, between less than 0.1 sec and 20 seconds depending on the electrode materials chosen and the inter-electrode gap. Voltage is seen when the gas between electrodes is air, hydrogen, or mixed gases and vapours, and is caused by the WE ionising the gas between electrodes, the LEC does not work in a vacuum. Results from the experiments carried out at Net Zero Scientific Ltd. exploring the materials parameter space show that co-deposition is not an absolute requirement and that a broad range of WE materials when loaded electrolytically with hydrogen without co-deposition also show behaviour characteristic of a LEC. These materials include aluminium, nickel, nickel mesh, titanium, ferrocenium, zirconium, samarium, and as powders, terbium, samarium cobalt alloy, and NdFeB alloy, Methods and both positive and null results are described, error-checking for artefacts was carried out and the methods used described.

1.0. LEC MECHANISMS EXPLORED.

To quote Frank Gordon/Harper Whitehouse directly, a Lattice Energy Converter (LEC):-

- Will spontaneously initiate the production of ionizing radiation and electrical energy based only on the thermal energy in its palladium lattice that is occluded with hydrogen or deuterium.
- Produces sustained ionizing radiation and electrical energy when the lattice material is in fluidic contact with a gas containing hydrogen or deuterium
- Does not require naturally radioactive materials
- Is mechanically simple to construct and test but the physics of its operation is not fully understood
- Easy to replicate

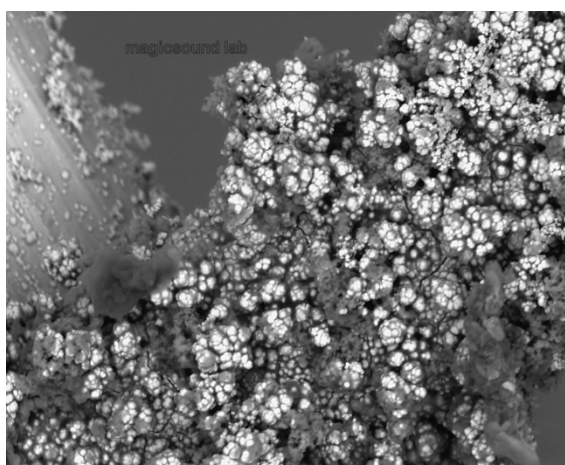
The hypothesis embraced by Gordon and Whitehouse is that the WE surface emits LENR radiation which ionises the free hydrogen/air between the WE and the CE. These ions separate into positive and negative species and produce a voltage across the electrodes. The only experimental evidence for particle emissions is that of Rout *et al*¹ who showed fogging of X-Ray film from similarly treated electrodes. At the time of writing this, no definitive evidence of particle emissions from LEC devices has been found by recent researchers even at very low energies.

Setting the (so far un-evidenced) LEC radiation hypothesis aside, LEC experimental results appear to be consistent with the description by K.K.Darrow² *et al*. Working in the 1930's Darrow described a diffusion driven device where differing ion mobilities and density variations lead to the production of a measurable voltage and current. De Boer³ (1935) describes how Pd, Fe, and Ni take up hydrogen at least partially in the form of protons and we can assume from changes in work function of metals when hydrided that these protons may also be present on the surface.

More recently D'us, Nowicka and Nowakowski⁴ discuss how ab/adsorbed hydrogen can lose or accept an electron, thus becoming either a proton or a negative ion. Experimental results in the literature show that both species can be present on and below the surface of various metals, but the process by which both species migrate into the bulk metal is not well understood. The mobility of protons in metals is much greater than that of negative hydrogen ions, so one suggestion is these negatively charged hydrogen species arise directly on the cathode surface and diffuse slowly into the bulk. Another possibility is that only protons diffuse into the lattice, following which some re-shuffling of bulk metal electrons occurs,

leading to the creation of negatively charged hydrogen species within the bulk. Shmal'no'ye, Klochko and Lotosky⁵ observed anomalies of electrical transfer in the gas phase of metal-hydride-hydrogen systems which they concluded were caused by the thermo-emission and vibrational excitation of H₂ molecules generated during recombination of H atoms on the metal hydride desorbed surface. However, if cathode outgassing effects were the only process, the LEC would only conduct electricity in one direction, like a gas diode, but this is not observed, suggesting that there is some kind of complimentary gas ionization must be occurring simultaneously in order to enable bi-directional conduction as is observed. It is also likely that an effect related entirely to outgassing would be relatively short lived, which is contrary to this observation of Gordon and Whitehouse. They have a 'sealed tube' LEC some 7 years old, which while it no longer produces significant spontaneous voltage still conducts current in both directions, indicating that ionised gas particles both positive and negative can still be produced.

Nobody thinking about the LEC for more than a few moments could overlook the matter of work function of the metals used. It is known that cathodic loading of hydrogen isotopes changes the work function of metals and the related surface charge distribution, something that is also influenced by the surface topography. Brian Ahern pointed out the potentially positive effects of nano-sculpting cathode surfaces 20 years ago, but more familiar perhaps is the swelling of gas loaded palladium which results in the formation of a new phase with different surface properties and structures. Gordon and Whitehouse are interested in the possibilities of using nano-machined cathodes, but it is well known that co-deposition plating processes create complex structures as shown below.



FG0005 2022/09/10 17:58 HMM10.2 x2.0k 30 μm

CO-DEPOSITED PALLADIUM ON S/STEEL MESH

Image courtesy Alan Goldwater.

This is the surface of a working electrode prepared by Gordon and Whitehouse. The extremely 'popcorned' surface offers a hugely increased area for ad/absorption of hydrogen compared with the stainless steel mesh substrate creating a high proportion of defects, interfaces and cracks which may contribute to the LEC effect in a number of ways.

1.1 *CHARGE TRANSPORT MATERIALS.*

A working LEC has three components, a working electrode (WE) capable of ionising a gas, a counter electrode (CE) and the charge transfer gas. In this regard, using the correct gas or gas mixtures is obviously important. For example oxygen, an electronegative gas has a greater affinity for electrons than hydrogen. Gordon and Whitehouse state that a hydrogen/air gas mixture shows greater difference in ion mobility and diffusivity than hydrogen gas alone. Equally, a Penning gas mixture involving argon or other inert gases might also produce useful differences in positive and negative ion mobility. Since the purpose of this project was to explore the material parameter boundaries and involved setting up and running 44 electrolysis experiments, voltage measurements reported here were carried out in air for speed and convenience. For many of the materials tested this did not seem to be problematic, the obvious exception being co-deposited iron plating (not tested here) which corrodes rapidly in air, particularly when electrolysed in acidic media.

Gas dynamics and its effect on LEC output is an area 'up for study'. For example, at lower pressure there is less gas to ionise but the ions move faster since they collide less, raised pressure produces more ions but they will move at lower velocity. As well as looking at the effect of filling the inter-electrode space with different pure or mixed gases it is possible that gas 'doping' whereby adding small amounts of acetone or ammonia vapour alters the number of charges the gas molecules will accept. H₂: For example, the ionisation potential of H₂ is 15.4eV, but that of acetone vapour is 9.7eV. That this makes a difference is obvious from experiments where acetone always increases the indicated voltage.

1.2 *POTENTIAL ARTEFACTS.*

Artefacts when measuring the microwatts of electricity produced by a first-generation LEC fall into a few broad categories, instrumentation error, induced voltages from nearby cables or instrumentation, galvanism, oxidation, photo and thermo-electric effects. These were the precautions taken to eliminate errors:-

1.2(a) *INSTRUMENTATION ERRORS.*

These are often unique to a particular instrument set-up and its physical location. The method used in this project was calibration/cross comparison between 2 instruments, using a variety of voltage sources including for the lower bound a K-type thermocouple and a 1.35V mercury battery for the upper bound. Reference instrumentation was a 5-1/2 digit Victor 8155 high-

impedance bench multimeter cross-calibrated with a 'Uni-Tut 404' battery-powered meter of long-proven accuracy.

1.2(b) *INDUCED VOLTAGES/GRID NOISE*

Net Zero Scientific's isolated laboratory location on a farm means there are low levels of ambient RFI and the fact that it has a dedicated supply meant that 'when in doubt' grid power to the entire building could be disconnected. This was found to be unnecessary after several trials, also a dedicated 'instrumentation grade' earth was used – a large copper plate buried in a soakaway drain.

1.2(c) *GALVANISM AND OTHER EFFECTS.*

Simple bi-metal junction effects can be ruled since the output of a LEC immediately falls to zero if there is even momentary direct electrical connection between WE and CE. This voltage is rapidly recovered when electrodes are separated, even after 24 hours of direct contact. Work function differences between electrodes affect output fairly predictably, but this could support many hypotheses as to the mechanism of voltage production. In response to suggestions that water vapour might be acting as a somehow 'special' charge carrier between electrodes of different work functions Gordon and Whitehouse carried out tests including freezing out water vapour from a cell at -55 °C but it continued to conduct current in the absence of any free water vapour. Also they state that the density of ions in a LEC is several orders of magnitude above that which could be attributed to water vapour alone at a similar temperature. Thermo-electric generation is another suggested mechanism, also discounted. LEC's have been tested in an oven at up to 200C. Voltage output increases with rising temperature, since the charge-carriers have greater kinetic energy but strictly speaking this is not a thermal energy conversion system 'as we know it' since the device is in an isothermal environment, there is no hot-cold junction. Conventional photo-electric effects have certainly been ruled out for Pd and Fe co-deposited electrodes, since many test systems consist of a WE enclosed in a light-proof tubular CE. It is accepted that some of the materials tested in the experiments described here may exhibit photo-electric effects, particularly samarium and possibly ceramics containing cerium so in these few isolated instances it cannot be entirely dismissed as contributory.

1.3 METHODOLOGY.

The experiments reported here were designed solely to discover if a wider range anode and cathode materials than has so far been reported on might be used to create LEC type systems. Initially this involved a number of 'scattergun' tests reported on LENR-Forum.com to gain familiarity with the requirements while a methodology was developed. Eventually a standardised electrolyte of 1.0M potassium carbonate in distilled water was settled on as being most useful in terms of handling on the bench and because of its generally non-aggressive effect on metals. Electrolysis was carried out using a voltage - controlled overpotential of at least 1V and total input power level of 1.0W from a smoothed DC PSU. 44 tests were carried out using cathode plates 4 x 3 cms approx, or powder samples of 30 grams with electrolysis times of 48 hours, many of them confirmation repeats and the results reported below are a simple average of often more than one measurement. Often four tests were performed simultaneously, so on any given day there were two 'mature' runs 48 hours old ready to measure, two 24 hour old ones to merely monitor, and 2 fresh tests to set up. Three tests were re-run because of uncertainty about the results, but were actually confirmatory, five others ended with minor mishaps which required a repeat. After electrolysis the WE was rinsed in distilled water, dried with a paper towel taking care to remove loose surface deposits and then air dried in a thermostatic oven at 60C for 90-120 minutes.

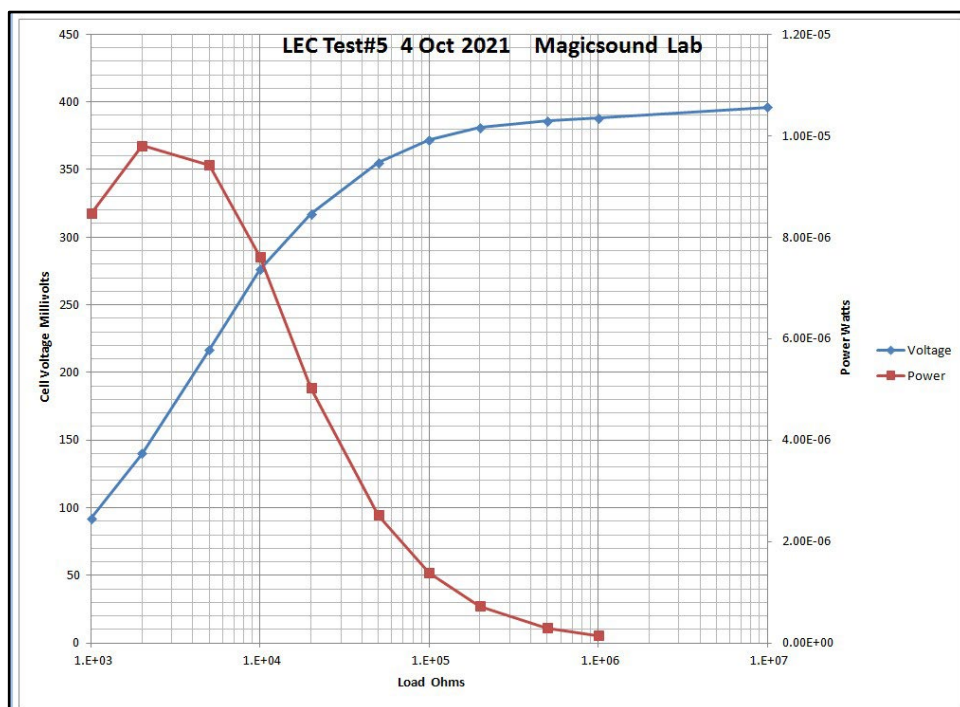
It is important to emphasise these tests only looked for the LEC effect as shown by production of a voltage between an electrolysed WE and a CE using a variety of materials. Gordon and Whitehouse, Di Stefano, J-P Biberian and Goldwater and this author have studied electrode longevity, current production, cell resistance and bi-directional conductivity in detail but the limited time available for so many tests made it necessary to leave such studies until later. Another key reason for using a simple and single voltage metric measured in air is that since the WE electrolysed areas used were not all absolutely identical current measurements could be misleading if compared. Variable electrode sizes – between 4 and 24 sq cm - have not been found to affect voltage production hugely, but current (generally in the micro-ampere range) does increase with plate area as might be expected. The less significant effect of WE surface area on expressed voltage can be shown simply by cutting an active WE in half, despite a 50% reduction on surface area the instantaneous open-circuit voltage generated rarely declines by more than 25%. This tends to confirm, albeit empirically, that there is no reduction in the energy of the gas ions, merely a reduction in their number.

1.3(a) *THE NATURE OF THE OUTPUT.*

Typically open-circuit voltage output as measured by many workers is of the order of 100-800mV. Gordon and Whitehouse's results suggest that the LEC behaves as a current source under load and a voltage source when open circuit. This complicates approaches to scaling up the usable voltage into an external load. The LEC appears to operate as a temperature dependent, diffusion driven current source, shunted by a voltage dependent conductance. Ed Storms in conversation at ICCF-24 has suggested the device is not only a 'possible but impractical' kind of battery but is of value in that it is potentially an extremely sensitive low-energy ionisation detector and, potentially, a very sensitive screening system for LENR activity. However the current series of tests using only light water and potassium carbonate electrolyte which shows LEC activity in a broad range of materials rather counts against the LENR theory, though admittedly some of the materials tested are known to be hydrogen-loving LENR 'probables' like Nickel, Terbium and Samarium.

1.4 *DISCUSSION OF RESULTS.*

Results from various exploratory experiments as well as those reported here have shown that creating a working LEC electrode is not highly dependent on the choice of cathode substrate, anode material, electrolyte, or electrolyte pH, nor is it particularly dependent on the co-deposition of metals onto the WE, or using just one kind of counter electrode or inter-electrode gas or vapour. Gordon and Whitehouse and Di Stefano have used HCl, while this author has run previous 'solo' tests using electrolytes containing FeCl₂, NiCl₂, FeSO₄, NH₃, ZnCl₂, KOH, K₂CO₃, NaHCO₃. Experiments using 75% Tetrahydrofuran and 25% distilled water saturated with potassium carbonate were performed with mixed results and are not reported here. All the measurements reported here were carried out in air, but it is known that a hydrogen-air mix and protic vapours like acetone give good or better results than air alone. Since demonstrating the simplicity and surprising ease with which the LEC effect can be seen in such a variety of materials and conditions was the primary purpose of this experiment it can be said that this has been achieved. Regrettably the wide focus of the experiments reported here have precluded doing careful studies of current levels, decay curves, cell resistance vs output and so on, but they do provide an insight into a phenomenon which has been observed and reported from time to time for the last hundred years but has evaded study to any serious degree for most of that time.



This plot of power out against voltage was made by Alan Goldwater's 'Magic Sound Lab' and is typical for a LEC. As can be seen increased resistance reduces power output, but voltage continues to climb smoothly until it plateaus at around 390mV. The LEC sample used here was co-dep Pd onto s/steel mesh prepared by Gordon and Whitehouse and shown on page 3.

During these tests and others various outliers have been observed. For example, two different types of ferrocerium (mischmetal) fire-starter rod were tested, known as 'soft' and hard'. These are made from impure cerium metal blended with iron and other oxides, similar to the material used for Zippo flints. When abraded with a piece of hard steel they produce hot sparks sufficient to ignite dry tinder. The soft variety sparks more readily than the hard, and probably contains more lanthanide material. When a trial - not included here - was made using zinc chloride electrolyte soft ferrocerium behaves more like a battery than a LEC suggesting there was residual chemical activity in the somewhat eroded bulk. A hard ferrocerium rod behaves exactly like other LEC metals. It is also interesting to note a useful puzzle. An isolated working electrode, in this case a co-dep Fe plated brass sheet connected to earth via a voltmeter showed zero voltage. An isolated counter-electrode connected to the same earth also showed no voltage (and this is a very good instrumentation earth being a large copper plate buried in wet soil and not part of the grid supply). Put the two electrodes together with a nylon mesh insulating spacer and a voltage appears, small at first, but steadily rising as the gas -space between electrodes becomes ionised. This rules out ongoing chemical activity, oxidation etc, within the bulk or on the surface of the WE but offers another testing method for such problems.



ELECTROLYSIS TANK USED FOR SOLID SAMPLES.

This is the zirconium cathode with a carbon rod anode in potassium carbonate/distilled water electrolyte running at 3.5V and a total power input of 1W, this wattage being selected as standard for all the tests, generally with a cathode overpotential of 1V or a little more. This image was taken shortly after starting electrolysis, which though not visible here produced copious amounts of hydrogen from the cathode. By the end of the run the hard carbon rod has deflagrated generously and the electrolyte is transformed into a brownish-black soup.

1.4(a) TABLE OF MATERIALS TESTED AND RESULTS..

WE - Cathode	Anode	Counter Electrode	Electrolyte	T (hrs)	V1 mV T+2h	V2 mV T+24h
Aluminium Plate	Carbon Rod	Aluminium Plate	K ₂ CO ₃	48	120	24
Aluminium Plate	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	144	21
Carbon Rod	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	0	0
Ferrocerium (soft)	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	610	444
Ferrocerium (hard)	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	340	120
Nickel Plate	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	240	188
Nickel Foam/Mesh	Carbon Rod	Nickel Foam/Mesh	K ₂ CO ₃	48	314	163
Nickel Foam/Mesh	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	342	226
Lead Plate	Lead Plate	Zinc Plate	K ₂ CO ₃	48	0	0
S/Steel (304) Plate	Zinc	Zinc Plate	K ₂ CO ₃	48	10	3
Ti (Powdered)	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	5	0
Terbium Chips	Lead Plate	Lead Plate	K ₂ CO ₃	48	462	355
Zirconium Plate	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	0	-
SmCo Powder	Lead Plate	Lead Plate	K ₂ CO ₃	48	0	-
Samarium Plate	Carbon Rod	Zinc Plate	K ₂ CO ₃	48	330	212

1.5 CONCLUSIONS. At some level LEC activity can be triggered by electrolysis of a variety of metals using non-metallic anodes without any need for co-deposition. Experiments suggest that lanthanides are of interest in this context since while none of the fine powders tested – including SmCo alloy magnet powder gave a positive result both Terbium in chip form (drilling waste) and solid pure Samarium did. The need for fluidic gaseous or mixed gas/vapours to transfer charge between WE and CE seems to be the only obligatory factor in all cases. Finally the use of identical metals for WE and CE shows that subtle and therefore undetected galvanic effects and work function differences are not critical factors. It is still in

this author's view impossible to be dogmatic about the mechanism of the LEC, but it would certainly appear to be an interesting method for studying methods and techniques of electrolytic hydrogen adsorption and may itself become a useful energy source one day.

Thanks are due to Frank Gordon, Harper Whitehouse and Alan Goldwater for their interest and support, and also to Fabrice David whose thoughts and suggestions will form the basis of a future study.

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